METHOD AND APPARATUS FOR CLEANING TRANSLUCENT TUBE FOR DISCHARGE LAMP, AND DISCHARGE LAMP

BACKGROUND OF THE INVENTION

The present invention relates to a method and an apparatus for cleaning a translucent tube for a discharge lamp. Furthermore, the present invention relates to a discharge lamp produced using a translucent tube that has been cleaned by such a cleaning method.

In recent years, an image projection apparatus such as a liquid crystal projector and a DMD projector has been widely used as a system for realizing large-scale screen images, and a high pressure discharge lamp having a high intensity (e.g., ultra high pressure mercury lamp and a metal halide lamp) has been commonly and widely used as the light source of such an image projection apparatus. Such a high pressure discharge lamp is produced by inserting an electrode assembly in which tungsten electrodes and metal foils are connected to each other into a glass tube for a discharge lamp (e.g., Japanese Laid-Open Patent Publication No. 10-321135).

FIG. **11** is a schematic cross-sectional view of a glass tube **100** for discharge lamp that is a translucent tube for a discharge lamp used to produce a high pressure discharge lamp. The glass tube **100** includes a substantially spherical luminous bulb portion **10** and a side tube portion **20** extending from the luminous bulb portion **10**. The luminous bulb portion

10 is a portion that becomes the luminous bulb of the high pressure discharge lamp, and the side tube portion **20** is a portion that becomes the sealing portion (seal portion) of the high pressure discharge lamp. The glass tube **100** is formed of quartz glass from which alkaline components are removed as much as possible. The alkaline components are removed as much as possible for the following reasons. When an alkaline component (e.g., Na) is present in the glass tube **100** (in particular, the luminous bulb portion **10**), the alkaline component becomes the seed of crystallization of the quartz glass, and crystallization of the quartz glass (phase transition to cristobalite) proceeds at a high temperature during lamp operation. As a result, the quartz glass becomes opaque. This phenomenon of becoming opaque is referred to as devitrification, and this is one factor that shortens the life of the discharge lamp. In order to suppress devitrification to prolong the life of the discharge lamp, the concentration of the alkaline components contained in the quartz glass constituting the glass tube for a discharge lamp is, for example, 1ppm or less.

Since the glass tube **100** for a discharge lamp is handled with care so that impurities are not attached thereto, it conventionally has been believed that substantially no alkaline component is attached to the glass tube **100** supplied from, for example, a manufacturer. In measurement of the inventors of the present invention, the alkaline component attached to the glass tube **100** is in an undetectable level.

Therefore, in the past, for example, when cleaning the glass tube **100**, the glass tube **100** was immersed in a container **170** to which pure water **160** was constantly supplied to clean the glass tube **100**, as shown in FIG. **12**.

However, the observation of the inventors of the present invention confirmed that even if the glass tube **100** having an alkaline component concentration of 1ppm or less is used to produce a discharge lamp, an influence of the alkaline component cannot be avoided. Although the inventors of the present invention handled the glass tube **100** under an inert atmosphere (e.g., argon) in order to prevent impurities from being mixed as much as possible in a production process of a discharge lamp, an influence of the alkaline component could not be eliminated. For this reason, when the glass tube **100** whose inner face was believed to have no alkaline component attached was tentatively cleaned and the impurity concentration of the alkaline component contained in the cleaning liquid was analyzed, the inventors of the present invention found that the alkaline component in a concentration of more than the alkaline component concentration in the quartz glass was attached on the inner face of the glass tube **100**. In other words, it was found that the level of the alkaline component of the glass tube **100** was higher than the alkaline component level of the original material (quartz glass) because of attachment of the alkaline component on the glass tube **100**.

In order to remove the alkaline component attached on

the glass tube **100** to return the alkaline level to that of the original material (e.g., an alkaline component concentration of 1ppm or less), it is not sufficient that the glass tube **100** is simply immersed in a flowing pure water, and a special cleaning is required. However, the glass tube **100** does not have a simple shape (e.g., not a disk shape as a semiconductor wafer), but has a complicated shape, so that it is difficult to clean the inner face of the glass tube **100**, especially the inner face of the luminous bulb portion **10**. This problem will be described further with reference to FIG. **13**.

In the case where the glass tube **100** is immersed in a container **170** filled with pure water **160**, generally an air bubble **32** is generated in the glass tube **100**, as shown in FIG. **13**. As shown in FIG. **12**, the glass tube **100** lies in the container **170**, an air bubble **32a** is present in an upper portion of the internal portion of the luminous bulb portion **10** of the glass tube **100**. This air bubble **32a** remains in the upper portion of the internal portion of the luminous bulb portion **10** of the glass tube **100**, even if the glass tube **100** is rotated or moved. Therefore, the air bubble **32a** prevents the pure water **160** from being in contact with the inner face of the luminous bulb portion **10**, so that the impurities present in the inner face of the luminous bulb portion **10** cannot be removed. Furthermore, also in the case of an air bubble **32b** that is present in a portion other than the luminous bulb portion **10**, as long as the air bubble **32b** is

present, the pure water **160** cannot be in contact with the inner face of the glass tube **100** in that portion, so that the impurities cannot be removed.

Furthermore, when a large air bubble **32c** that blocks the internal portion of the glass tube **100** is present, the pure water **160** cannot flow in the internal portion of the glass tube **100**, even if the pure water **160** continues to flow in the container **170**. Therefore, the inner face of the glass tube **100** substantially cannot be cleaned. The reason is as follows. When the pure water **160** in the internal portion of the glass tube **100** stop flowing, even if the impurities present in the inner face of the glass tube **100** are dissolved in the pure water **160**, the impurities cannot go out from the glass tube **100**. Therefore, when glass tube **100** is dried after cleaning, the impurities are attached on the inner face of the glass tube **100** again. Therefore, unless the pure water **160** flows in the internal portion of the glass, the inner face cannot be cleaned, although the outer face of the glass tube **100** can be cleaned. In addition, even if there is no air bubbled **32** in the glass tube **100**, the inner diameter of the glass tube **100** is not so large that the flow of the pure water **160** in the glass tube **100** is not satisfactory, or rather the pure water **160** hardly flows.

This is a problem not only in the case where the pure water **160** flows in the container **170**, but this problem also occurs when cleaning the glass tube **100** immersed in the container **170** with ultrasonic waves. In other words, even if

the impurities are ready to be dissolved in the pure water by applying ultrasonic waves, the impurities are eventually attached on the inner face of the glass tube **100** after drying, unless the impurities go out from the glass tube **100**. Furthermore, a method of cleaning by inserting a rotating brush into the glass tube **100** causes scratches on the inner face of the glass tube **100**, and therefore this is not practical.

SUMMARY OF THE INVENTION

Therefore, with the foregoing in mind, it is a main object of the present invention to provide a method for cleaning away the impurities attached on the inner face of a translucent tube for a discharge lamp.

A method for cleaning a translucent tube for a discharge lamp having a luminous bulb portion includes the steps of introducing a cleaning fluid from one end of the translucent tube; and allowing the cleaning fluid to flow while bringing the cleaning fluid in contact with at least an inner face of the luminous bulb portion of an inner face of the translucent tube, thereby removing impurities attached on the inner face of the luminous bulb portion.

It is preferable that in the step of removing impurities, the cleaning fluid is allowed to flow while being in contact with an outer face of the translucent tube in the same step, thereby removing impurities attached on the outer face of the translucent tube.

It is preferable that the step of introducing a cleaning fluid includes the steps of disposing the translucent tube in a container for containing a cleaning liquid as the cleaning fluid such that ends of the tube are positioned in a substantially vertical direction; and injecting the cleaning liquid into the container. The step of removing impurities includes the steps of elevating a liquid surface of the cleaning liquid above an upper portion of the luminous bulb portion of the translucent tube for a discharge lamp; and lowering the liquid surface of the cleaning liquid below a lower portion of the luminous tube portion.

It is preferable that the step of elevating the liquid surface of the cleaning liquid and the step of lowering the liquid surface of the cleaning liquid are repeated.

It is preferable that the step of lowering the liquid surface of the cleaning liquid is performed such that the liquid surface of the cleaning liquid is lowered below a lower end of the translucent tube.

It is preferable that the step of elevating the liquid surface of the cleaning liquid is performed such that the liquid surface of the cleaning liquid is elevated above an upper end of the translucent tube.

It is preferable that the method further includes the step of discharging the cleaning liquid in the container from the container.

In one embodiment, the ending point of cleaning is

determined by monitoring the concentration of the impurities contained in the cleaning liquid in the container.

It is preferable that the translucent tube is disposed using a holding tool for holding a plurality of translucent tubes such that ends of the tubes are positioned in a substantially vertical direction.

In one embodiment, the cleaning liquid is one selected from the group consisting of ultrapure water (the value of resistance: e.g., about 10MΩ or more), pure water (the value of resistance: e.g., about 1MΩ or more), deionized water (the value of resistance: e.g., about 1MΩ - 10MΩ or more), hydrofluoric acid aqueous solution and hydrogen peroxide aqueous solution, and a combination of one of these cleaning liquids and cleaning fine particles.

In one embodiment, a plurality of kinds of impurities are attached on the inner face of the luminous bulb portion as the impurities, and the method includes at least a first step of introducing a first cleaning liquid as the cleaning liquid from the one end of the translucent tube with respect to a first kind of impurities of the plurality of kinds of impurities, and a second step of introducing a second cleaning liquid other than the first cleaning liquid as the cleaning liquid from the one end of the translucent tube with respect to a second kind of impurities other than the first kind of impurities of the plurality of kinds of impurities.

In one embodiment, the cleaning fluid is either one of gas, liquid, or fine particle powder, and the step of

removing impurities attached on the inner face of the luminous bulb portion is performed by discharging the cleaning fluid introduced from one end of the translucent tube for a discharge lamp from the other end of the translucent tube for a discharge lamp.

In one embodiment, the cleaning fluid is inert gas (e.g., argon gas or nitrogen gas).

According to another aspect of the present invention, an apparatus for cleaning a translucent tube for a discharge lamp includes a container for accommodating a translucent tube for a discharge lamp having a luminous bulb portion and for containing a cleaning liquid; an injection pipe or an injection tube through which the cleaning liquid is injected into the container; a discharge pipe or a discharge tube through which the cleaning liquid in the container is discharged; and a concentration monitoring meter for monitoring a concentration of impurities that was attached on the translucent tube and is contained in the cleaning liquid in the container.

It is preferable that the concentration monitoring meter has a function to determine an end of cleaning by comparing an electrical conductivity of the cleaning liquid in the container or the cleaning liquid discharged from the container with a reference value, an electrical conductivity of the cleaning liquid injected to the injection pipe or the injection tube being used as the reference value.

In one embodiment, the container has an airtight

structure that prevents the cleaning liquid in the container from being in contact with air outside the container.

According to another aspect of the present invention, a discharge lamp comprising a luminous bulb and sealing portions extending from the luminous bulb, the luminous bulb enclosing a luminous material and including a pair of electrodes opposed to each other therein, wherein the discharge lamp is produced by a method for producing a discharge lamp including the steps of preparing a translucent tube for a discharge lamp including a luminous bulb portion that becomes a luminous bulb of the discharge lamp, and side tube portions extending from the luminous bulb portion, the translucent tube having been subjected to a cleaning process; inserting an electrode assembly including metal foils and electrodes connected to the metal foils into the side tube portion such that the heads of the electrodes are positioned inside the luminous bulb portion; and forming the sealing portions by tightly attaching the metal foils of the electrode assembly to the side tube portions. The cleaning process includes the steps of (a) introducing a cleaning fluid from one end of a translucent tube for a discharge lamp including a luminous bulb portion that becomes a luminous bulb of the discharge lamp, and side tube portions extending from the luminous bulb portion; and (b) allowing the cleaning fluid to flow while bringing the cleaning fluid in contact with at least the inner face of the luminous bulb portion of the inner face of the translucent tube, thereby removing

impurities attached on the inner face of the luminous bulb portion. The step (a) includes a step (a-1) of disposing the translucent tube in a container for containing a cleaning liquid as the cleaning fluid so that ends of the translucent tube are positioned in a substantially vertical direction; and a step (a-2) of injecting the cleaning liquid into the container. The step (b) includes a step (b-1) of elevating a liquid surface of the cleaning liquid above an upper portion of the luminous bulb portion of the translucent tube; and a step (b-2) of lowering the liquid surface of the cleaning liquid below a lower portion of the luminous tube portion.

In one embodiment of the discharge lamp, as the luminous material, at least mercury, a rare gas and halogen are enclosed in the luminous bulb, and the luminous bulb is made substantially of quartz glass, and the electrodes are made substantially of tungsten, and the mole number of the halogen is larger than the sum of the total mole number of metal elements that have the property of bonding to the halogen and are present in the luminous bulb (except for tungsten and mercury), and the mole number of the tungsten present in the luminous bulb after evaporated from the electrodes during lamp operation. In addition to that, when each kind of the metal elements (except for tungsten element and mercury element) is **Mi**, the mole number of the metal element **Mi** is **mi**, and the stoichiometric coefficient of the metal element **Mi** is **ni**, the mole number of the halogen is larger than the sum of the total number ($\sum(mi \times ni)$) obtained

by adding the numbers obtained by multiplying the mole number **mi** of the metal element **Mi** by the stoichiometric coefficient **ni** with respect to each kind of the metal elements **Mi**, and the mole number of the tungsten.

In one embodiment, the mole number of the halogen enclosed in the luminous bulb is not less than five times the total mole number of sodium (Na), potassium (K), lithium (Li), chromium (Cr), iron (Fe) and nickel (Ni) present in the luminous bulb.

In one embodiment, the discharge lamp is a mercury lamp in which a bulb wall load of the luminous bulb is $80 W/cm^2$ or more.

According to the present invention, a cleaning fluid is introduced from one end of a translucent tube for a discharge lamp (e.g., glass tube or ceramic tube for a discharge lamp), and the cleaning fluid is allowed to flow while bringing the cleaning fluid in contact with at least the inner face of the luminous bulb portion. Thus, the impurities attached on the inner face of the luminous bulb portion can be removed satisfactorily by constantly introducing new cleaning fluid to the inner face of the luminous bulb portion.

Furthermore, when the cleaning fluid is allowed to flow while bringing the cleaning fluid in contact with, not only the inner face of the luminous bulb portion, but also the outer face of the translucent tube, the impurities attached on the outer face of the translucent tube as well as the impurities attached on the inner face thereof can be removed.

As a result, the impurities (especially, fingerprints or oils and fats of workers) attached on the outer face of the translucent tube can be removed, so that the devitrification of the luminous bulb that may occur during lamp lighting due to the impurities can be prevented.

In the case where a cleaning liquid is used as the cleaning fluid, the cleaning liquid is allowed to flow while being in contact with the inner face of the luminous bulb portion in the following manner. A translucent tube is disposed in a container in which a cleaning liquid is to be poured so that the ends of the tube are positioned in a substantially vertical direction, and then the liquid surface of the cleaning liquid is elevated above the upper portion of the luminous bulb portion. Thereafter, the liquid surface of the cleaning liquid is lowered below the lower portion of the luminous bulb portion. In this case, it is preferable to repeat the process of elevating the liquid surface of the cleaning liquid and the process of lowering the liquid surface of the cleaning liquid. When the liquid surface of the cleaning liquid is lowered below the lower end of the translucent tube, the cleaning liquid having a high content of impurities can be discharged from the tube, so that the impurities attached on the inner face of the translucent tube can be removed satisfactorily. Also when the liquid surface of the cleaning liquid is elevated above the upper end of the translucent tube, the cleaning liquid having a high content of impurities can be discharged from the tube. Furthermore,

this is also preferable, because the entire inner face of the translucent tube can be in contact with the cleaning liquid. It is more preferable to discharge the cleaning liquid in the container from the container, because the cleaning liquid containing impurities can be replaced by a cleaning liquid that has not been subjected to cleaning yet. Furthermore, when cleaning is performed while monitoring the concentration of the impurities contained in the cleaning liquid, it is possible to easily determine the time at which the impurities are removed completely (end of cleaning).

In the case where a holding tool for holding a plurality of translucent tubes for a discharge lamp is used, the plurality of translucent tubes can be cleaned, so that working efficiency can be improved. As the cleaning liquid, ultrapure water, pure water, deionized water, hydrofluoric acid aqueous solution, and hydrogen peroxide aqueous solution can be used, and a combination of one of these cleaning liquids and cleaning fine particles can be used. As the cleaning liquid, for example, ultrapure water is used, an alkaline component can be removed satisfactorily. In the case where a plurality of kinds of impurities are attached on the inner face of the luminous bulb portion, a first cleaning liquid is used with respect to a first kind of impurities, and a second cleaning liquid is used with respect to a second kind of impurities to clean the translucent tube.

Furthermore, as the cleaning fluid, either gas, liquid, or fine particle powder can be used to remove the impurities

attached on the inner face of the luminous bulb portion by discharging the cleaning fluid introduced from one end of the translucent tube for a discharge lamp from the other end of the translucent tube for a discharge lamp. As the cleaning fluid, for example, inert gas such as argon gas and nitrogen gas can be used.

An apparatus for cleaning a translucent tube for a discharge lamp of the present invention includes an injection pipe (or injection tube) through which a cleaning liquid is injected into a container for accommodating the translucent tube for a discharge lamp, a discharge pipe (or discharge tube) through which the cleaning liquid is discharged from the container, and a concentration monitoring meter for monitoring the concentration of the impurities contained in the cleaning liquid in the container. Therefore, the impurity concentration can be monitored while cleaning, which can ensure the cleaning of the translucent tube for a discharge lamp. If the concentration monitoring meter has a function to determine the end of cleaning, the ending point of cleaning can be determined easily. In the case where the concentration monitoring meter is used, for example, the time at which the electrical conductivity of the cleaning liquid in the container or the cleaning liquid discharged from the container is substantially equal to a reference value can be set as the ending point of cleaning. Furthermore, in the case where the container has an airtight structure so that the cleaning liquid in the container is not in contact with

the air outside the container, it is possible to prevent impurities contained in the air outside the container from being mixed with the cleaning liquid in the container.

In a discharge lamp produced with the translucent tube for a discharge lamp cleaned by the method for cleaning a translucent tube for a discharge lamp of the present invention, the impurities are removed satisfactorily, so that the discharge lamp has higher performance (e.g., longer lifetime) than those in the prior art.

According to the present invention, cleaning fluid is introduced from one end of a translucent tube for a discharge lamp (e.g., glass tube for a discharge lamp), and the cleaning fluid is allowed to flow while bringing the cleaning fluid in contact with at least the inner face of the luminous bulb portion. Therefore, the impurities attached on the inner face of the luminous bulb portion can be removed satisfactorily. As a result, the impurities (e.g., alkaline components) attached on the inner face of the luminous bulb portion can be cleaned away to the same concentration level as that of the impurities of the material (quartz glass) constituting the glass tube for a discharge lamp. Therefore, the present invention can produce a discharge lamp having a long lifetime in which devitrification or the like can be prevented.

This and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with

reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A** to **1C** are cross-sectional views for illustrating a method for cleaning a translucent glass tube for a discharge lamp of an embodiment of the present invention.

FIGS. **2A** and **2B** are views for illustrating a method for cleaning a translucent tube for a discharge lamp of Embodiment **1**.

FIG. **3** is a perspective view showing a structure of a cleaning apparatus **70**.

FIG. **4** is a perspective view showing a structure of a holding tool **90**.

FIG. **5** is a cross-sectional view showing a variation of the cleaning apparatus **70**.

FIG. **6** is a flowchart showing each process of a cleaning method of Embodiment **2**.

FIG. **7** is a flowchart showing the production process of a discharge lamp of Embodiment **3**.

FIGS. **8A** to **8C** are cross-sectional views for illustrating a lamp production process **S300**.

FIG. **9** is a cross-sectional view schematically showing a structure of a discharge lamp **1000** of Embodiment **3**.

FIG. **10** is a cross-sectional view schematically showing a structure of a lamp provided with a mirror **1200**.

FIG. **11** is a cross-sectional view of a glass tube for a

discharge lamp.

FIG. **12** is a view for illustrating a method for cleaning a glass tube for a discharge lamp.

FIG. **13** is a view for illustrating a problem of a method for cleaning a glass tube for a discharge lamp.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings. In the following drawings, for simplification, elements having substantially the same functions have the same reference numerals.

FIGS. **1A** to **1C** are cross-sectional views schematically showing each process of a method for cleaning a translucent tube for a discharge lamp of en embodiment of the present invention.

First, a glass tube **100** for a discharge lamp that is a translucent tube for a discharge lamp having a substantially spherical luminous bulb portion **10** and side tube portions **20** is prepared. The inner diameter and the glass thickness of the luminous bulb portion **10** of the glass tube **100** prepared in this embodiment are 6mm and 3mm, respectively. The inner diameter and the length in the longitudinal direction of the side tube portion **20** is 3.4mm and 250mm, respectively. The glass tube **100** is formed of quartz glass, for example, having an alkaline component concentration of 1 to 2ppm, preferably 1ppm or less. Impurities **30** are attached on the inner face

(e.g., inner face **10a** of the luminous bulb portion **10**) of the prepared glass tube **100** before cleaning. Examples of the impurities **30** include alkaline components (Na, K etc.), silica powder, and organic substances. In this embodiment, a glass tube for a discharge lamp is used, but the glass tube for a discharge lamp can be replaced by a ceramic tube for a discharge lamp.

As shown in FIG. **1A**, cleaning fluid **50** is introduced from one end **100a** of the glass tube **100**. The introduced cleaning fluid **50** flows while being in contact with the inner face **10a** of the luminous bulb portion **10**, as shown in FIG. **1B**, and impurities **30** attached at least on the inner face **10a** of the luminous bulb portion **10** are removed, as shown in FIG. **1C**. Then, the cleaning fluid **50** is discharged from the other end **100b** of the glass tube **100**, and thereafter new cleaning fluid **50′** is introduced from the one end **100a** of the glass tube **100**, and the impurities **30** are removed by the cleaning fluid **50′**. This introduction of cleaning fluid is repeated, and at the point where all the attached impurities **30** are removed, the glass tube **100** has been cleaned to the same concentration level as that of the impurities contained in the material (quartz glass) constituting the glass tube **100**.

According to the cleaning method of this embodiment, the cleaning fluid **50** flows while being in contact with the inner face **10a**, so that the cleaning fluid **50** washes away the impurities **30**. Furthermore, it is possible to remove the impurities **30** in an infinite dilution manner by replacing the

cleaning fluid **50** in the glass tube **100** by new cleaning fluid. On the other hand, in the cleaning method shown in FIG. **12**, even if the glass tube **100** is moved more or less, the pure water in the glass tube **100** is hardly moved, and the pure water in the glass tube **100** can hardly be replaced. For this reason, in the cleaning method shown in FIG. **12**, removal of impurities is performed by diffusing the impurities in substantially stationary pure water. Therefore, the cleaning method of this embodiment can remove the impurities **30** from the tube more satisfactorily.

As the cleaning fluid **50** in this embodiment, either gas (argon gas), liquid (cleaning liquid) or fine particle powder (quartz beads) can be used. The cleaning fluid introduced from one end **100a** of the glass tube **100** is discharged only from the other end **100b**, as shown in FIG. **1C**, but also from the one end **100a** when the cleaning fluid is, for example, a cleaning liquid.

Hereinafter, an embodiment will be described in the case where a cleaning liquid is used as the cleaning fluid, and a glass tube for a discharge lamp is used as the translucent tube for a discharge lamp. However, the present invention is not limited by the following embodiments. For example, a ceramic tube for a discharge lamp can replace the glass tube for a discharge lamp.

<u>Embodiment 1</u>

A method for cleaning a glass tube for a discharge lamp

with a cleaning liquid as the cleaning fluid will be described with reference to FIGS. **2A** and **2B**. FIGS. **2A** and **2B** schematically show each process of a cleaning method of Embodiment **1**.

First, as shown in FIG. **2A**, a glass tube **100** for a discharge lamp is disposed in a container **72** of a cleaning apparatus **70** provided with the container **72** for containing a cleaning liquid **60**. The glass tube **100** is disposed so that the ends of the glass tube **100** are in a substantially vertical direction. One end **100a** of the glass tube **100** is positioned in a lower portion of the container **72**.

Next, the cleaning liquid **60** is injected into the container **72** through an injection pipe (or injection tube) **74** for injection of the cleaning liquid **60** into the container **72**. The amount of the cleaning liquid **60** to be injected can be adjusted by a valve **75**. As the cleaning liquid **60** is injected into the container **72**, the liquid surface **60a** of the cleaning liquid **60** is elevated. Therefore, after the cleaning liquid **60** is introduced from one end **100a** of the glass tube **100**, the cleaning liquid **60** in the glass tube **100** flows upward while being in contact with the inner face of the glass tube **100**. The injection of the cleaning liquid **60** continues and the cleaning liquid **60** in the glass tube **100** is allowed to flow while being in contact with the inner face **10a** of the luminous bulb portion **10**, so that the impurities (not shown) attached on the inner face **10a** of the luminous bulb portion **10** are removed.

In this case, the cleaning liquid **60** flows upward while in contact with not only the inner face of the glass tube **100**, but also the outer face of the glass tube **100**. Therefore, not only the impurities attached on the inner face **10**a of the luminous bulb portion **10**, but also the impurities attached on the outer face (especially, outer face of the luminous bulb portion **10**) of the glass tube **100** are removed. In the outer face of the glass tube **100**, finger prints or oils and fats of workers containing much of impurities such as sodium are readily attached. It is not preferable that they remain on the luminous bulb of a discharge lamp, because this may cause devitrification. More specifically, since the temperature is increased not only in the inner face of the luminous bulb, but also the outer face during lamp lighting, and therefore finger prints or oils and fats are burned and attached thereto, which may cause devitrification. In this embodiment, the outer face of the glass tube **100** as well as the inner face thereof can be cleaned, so that such devitrification can be prevented effectively. In addition, the inner face and the outer face of the glass tube **100** can be cleaned at the same time, so that working efficiency is good.

At the point where the liquid surface **60a** of the cleaning liquid **60** is elevated above the upper portion of the luminous bulb portion **10**, the entire inner face **10a** of the luminous bulb portion **10** has been cleaned with the cleaning liquid **60**. Thereafter, the injection of the cleaning liquid **60** from the injection pipe **74** continues so that the liquid

surface **60a** of the cleaning liquid **60** is elevated until the liquid surface reaches a predetermined height in the container **72**, preferably, above the upper end of the glass tube **100**. When the liquid surface **60a** is elevated above the upper end of the glass tube **100**, the cleaning liquid **60** can be in contact with the entire inner face of the glass tube **100**. In addition, the cleaning liquid **60** can be replaced by discharging the cleaning liquid **60** in the tube from the upper end of the glass tube **100**. Furthermore, for example, when dust is present on the liquid surface **60a**, it is possible to prevent the dust from being attached and remaining on the inner face of the tube.

Next, as shown in FIG. **2B**, the cleaning liquid **60** in the container **72** is discharged through a discharge pipe (discharge tube) **76** for discharge of the cleaning liquid **60** in the container **72** to lower the liquid surface **60a** of the cleaning liquid **60**. In this embodiment, the cleaning liquid **60** is injected into the container **72** through the injection pipe **74** in the state where both the valve **75** of the injection pipe **74** and the valve **75** of the discharge pipe **76** are open, so that the liquid surface **60a** of the cleaning liquid **60** is elevated to the height of the uppermost portion **76h** of the discharge pipe **76**. When the liquid surface **60a** reaches the uppermost portion **76h**, the cleaning liquid is discharged (drained) automatically on the principle of siphon. When the inner diameter of the discharge pipe **76** is larger than that of the injection pipe **74**, the discharge liquid **60** can be

completed without stopping the injection of the cleaning liquid **60**. Thus, the up and down of the liquid surface **60a** can be repeated infinitely. Furthermore, the up and down of the liquid surface **60a** can be performed by adjusting the valve **75** of the injection pipe **74** and the valve **75** of the discharge pipe **76**. Alternatively, the discharge pipe (liquid removing pipe) is provided in a lower portion of the container **72** or on the bottom face of the container **72**, so that the cleaning liquid **60** can be discharged from the discharge pipe. In this case, after the injection of the cleaning liquid **60** is stopped, the cleaning liquid **60** is discharged.

When the liquid surface of the cleaning liquid **60** is lowered below the lower portion of the luminous bulb portion **10** by the discharge of the cleaning liquid **60**, the cleaning liquid **60** moves while being in contact with the inner face **10a** of the luminous bulb portion **10**. In this embodiment, the cleaning liquid **60** in the tube is removed by lowering the liquid surface **60a** below the lower end **100a** of the glass tube **100**, and the liquid surface **60a** is elevated again by new cleaning liquid **60** that is constantly injected from the injection pipe **74**. Thus, cleaning can be performed while replacing the entire cleaning liquid **60** in the glass tube **100**.

After the liquid surface **60a** of the cleaning liquid **60** is lowered below the lower portion of the luminous bulb portion **10**, the liquid surface **60a** can be elevated again. In this case, the inner face of the glass tube **100** can be

cleaned while replacing a part of the cleaning liquid **60** in the glass tube **100** by a part of the cleaning liquid **60** outside the tube. Furthermore, it is possible to combine the method of partially replacing the cleaning liquid **60** in the tube and the method of entirely replacing the cleaning liquid **60** in the tube. In this embodiment, the liquid surface **60a** is elevated and lowered by the injection and the discharge of the cleaning liquid **60**. However, the liquid surface **60a** can be elevated and lowered by physically moving the glass tube **100** up and down (e.g., mechanically or manually).

The glass tube **100** is cleaned by repeating elevating and lowering the liquid surface **60a** a plurality of times. In this embodiment, for example, a set of elevating and lowering the liquid surface **60a** is performed over about 5 minutes, and cleaning is carried out by performing the total of five sets.

When it is desired to clean the glass tube **100** sufficiently within a necessity minimum time while confirming that cleaning is completed, the end of cleaning can be determined by monitoring the concentration of the impurities contained in the cleaning liquid **60** in the container **72**. For example, cleaning can be performed while monitoring with a concentration monitoring meter whether or not the concentration of the impurities in the cleaning liquid **60** to be injected to the injection pipe **74** and the concentration of the impurities in the cleaning liquid **60** in the container **72** are within a predetermined range (or substantially equal). The concentration of the impurities in the cleaning liquid **60**

discharged from the container **72** can be monitored instead of the concentration of the impurities of the cleaning liquid **60** in the container **72**.

The concentration of the impurities contained in the cleaning liquid **60** can be measured, for example, with an electrical conductivity meter. More specifically, as shown in FIGS. **2A** and **2B**, using an electrical conductivity meter **82** for measuring the electrical conductivity of the cleaning liquid **60** in the container **72** and a concentration monitoring meter **80** provided with a monitor **84** showing the indicated value of the electrical conductivity meter **82**, the end of cleaning can be determined. First, before disposing the glass tube **100** in the container **72**, the cleaning liquid (e.g., pure water or ultrapure water) **60** to be injected to the injection pipe **74** is poured, for example, in the container **72**, and the electrical conductivity of the cleaning liquid **60** is measured with the electrical conductivity meter **82**, and the indicated value obtained by the measurement is used as the reference value. Thereafter, when cleaning the glass tube **100**, the electrical conductivity of the cleaning liquid **60** in the container **72** is compared with the reference value, so that the end of cleaning can be determined. Furthermore, the electrical conductivity meter is placed in a cleaning liquid supply tank (not shown) of the cleaning liquid **60** to be injected to the injection pipe, and the indicated value from the electrical conductivity meter can be used as the reference value.

Next, an apparatus and a tool suitably used in the cleaning method of Embodiment **1** will be described with reference to FIGS. **3** and **4**. FIG. **3** is a perspective view showing the structure of the cleaning apparatus **70** shown in FIG. **2**. FIG. **4** is a perspective view of a holding tool **90** for holding a plurality of glass tubes **100** for a discharge lamp positioned substantially in the vertical direction.

The cleaning apparatus **70** shown in FIG. **3** includes a container **72** for containing a cleaning liquid **60** into the container **72**, an injection pipe **74** through which the cleaning liquid **60** is injected, and a discharge pipe **76** through which the cleaning liquid **60** in the container **72** is discharged. The cleaning apparatus **70** further includes a concentration monitoring meter **80** (see FIG. **2**) for monitoring the concentration of the impurities contained in the cleaning liquid **60** in the container **72** (impurities attached on the glass tube **100**), which is not shown in FIG. **3**. The container **72**, the injection pipe (or injection tube) **74**, and the discharge pipe (or discharge tube) **76** of the cleaning apparatus **70** are made of polyvinylchloride (thickness: for example, about 5mm) so as to prevent impurities of the materials constituting these members from being mixed with the cleaning liquid **60**. Instead of polyvinylchloride, PTFE (e.g., Teflon (registered trademark)) can be used.

The upper face of the container **72** is open, and glass tube **100** is inserted from the opening on the upper face so that glass tube **100** can be disposed in the container **72**.

After disposing the glass tube **100** in the container **72**, it is desired to set a lid **78** on the upper face of the container **72** so as to shut off dust or the like from the container **72**. The upper face and the lower face of the container **72** are squares having a side of about 310mm, and the height of the container **72** is, for example, about 505mm. The shape of the container **72** may be a rectangle having rectangular top and bottom faces, or may be a cylinder having circular top and bottom faces.

The injection pipe **74** has one end **74a** from which the cleaning liquid (e.g., pure water) **60** is introduced, and the other end **74b** from which the cleaning liquid **60** is supplied to the container **72**. The one end **74a** is positioned outside the container **72**, and the other end **74b** is positioned in the container **72**. When injecting the cleaning liquid **60**, for example, a hose made of polyvinylchloride can be connected to the one end **74a**. In this embodiment, the injection pipe **74** penetrates the side of the container **72** at a predetermined portion **74c**, and a valve **75** for adjusting the amount of the cleaning liquid **60** to be injected is provided between the one end **74a** and the other end **74b** of the injection pipe **74**.

The discharge pipe **76** has one end **76a** positioned in the container **72** and the other end **76b** positioned outside the container **72**. The one end **76a** of the discharge pipe **76** is provided in a lower portion of the container **72**, preferably in a portion lower than the lower end of the glass tube **100** disposed in the container **72**. When the one end **76a** of the

discharge pipe **76** is provided in a portion lower than the lower end of the disposed glass tube **100**, the following advantage is provided. When the cleaning liquid **60** is discharged, the liquid surface **60a** of the cleaning liquid **60** can be lowered below the lower end of the glass tube **100**. As a result, the entire cleaning liquid **60** in the tube can be let out from the glass tube **100**. Furthermore, it is preferable to provide the uppermost portion **76h** of the discharge pipe **76** in a portion higher than the upper portion of the luminous bulb portion **10** of the disposed glass tube **100**, when discharging the cleaning liquid **60** from the discharge pipe **76** using the principle of siphon. It is more preferable to provide the uppermost portion **76h** in a portion higher than the upper end of the disposed glass tube **100**. Since the valve **75** is provided in the discharge pipe **76**, discharge can be adjusted and controller by the valve **75**. In this embodiment, apart from the discharge pipe, a pipe **77** for liquid removal provided with a valve **75** for the purpose of removing the cleaning liquid **60** is provided in a lower portion of the side of the container **72**. Therefore, the cleaning method of this embodiment can be performed by using the pipe **77** for liquid removal as the discharge pipe without using the discharge pipe **76**.

Next, a holding tool **90** for holding a plurality of glass tubes **100** for discharge lamps will be described. The holding tool **90** of FIG. **4** includes a holding plate **94** having openings **98** through which the side tube portions **20** of the

glass tube **100** pass and the luminous bulb portions **10** do not pass, and a supporting rod **92** for supporting the holding plate **94**. The holding plate **94** is attached to the supporting rod **92** that the holding plate **94** is substantially horizontal, so that the glass tubes **100** can be positioned in the substantially vertical direction by inserting the glass tubes **100** into the openings **98** of the holding plate **94**. About one hundred openings **98** are provided in the holding plate **94**, and therefore, using the holding tool **90**, about one hundred glass tubes **100** can be cleaned at one time.

Below the holding plate (upper plate) **94**, there are a middle plate **95** that prevents the side tube portions **20** of the glass tubes **100** from moving freely, and a lower plate **96** that is provided under the middle plate **95** and is to be disposed on a stand **97**. In addition to the holding plate (upper plate) **94**, the middle plate **95** and the lower plate **96** are also supported by the supporting rod **92**, and when the glass tubes **100** are set into the holding tool **90**, the lower ends of the glass tubes **100** are positioned between the middle plate **95** and the lower plate **96**. It is not necessary that the lower plate **96** and the stand **97** are provided with openings through which the glass tubes pass, but it is desired that the lower plate **96** and the stand **97** are provided with the openings **98** so that the cleaning liquid **60** can be let in and out satisfactorily. Furthermore, this is preferable, because the same member as those of the upper plate **94** and the middle plate **95** can be used to produce the

tool.

A handle **92a** used to lift the holding tool **90** is formed in an upper portion of the supporting rod **92**, and the holding tool **90** can be disposed in the container **72** of the cleaning apparatus **70** with the handle **92a**. Therefore, after a plurality of glass tubes **100** are set in the holding portion **90**, the stand **97** is disposed on the bottom face of the container **72**, and then the holding tool **90** is moved into the container **72** with the handle **92a**, so that each of the plurality of glass tubes **100** can be disposed in the container **72**, each positioned in a substantially vertical direction. When the cleaning liquid **60** is poured in the container **72**, the holding tool **90** is stabilized in the container **72** by its self-weight, and thus the glass tubes **100** can be positioned stably in the container by the holding tool **90**.

The stand **97** supporting the holding tool **90** is larger that the lower plate **96** of the holding tool **90**, and a notch **97**a is provided in the stand **97** so that a portion in the vicinity of the one end **76a** of the discharge pipe **76** is not overlapped with the stand **97**, when the stand **97** is disposed on the bottom face of the container **72**. When disposing the holding tool **90** on the stand **97**, it is preferable that an opening provided in the lower plate **96** of the holding tool **90** is matched with the opening provided in the stand **97**, because the cleaning liquid **60** can be let in and out satisfactorily.

The members (e.g., the holding plate **94** and the supporting rod **92**) constituting the holding tool **90** are

formed of, for example, polyvinylchloride so as to prevent impurities from being mixed in the cleaning liquid **60.** In this embodiment, a gap h_1 between the upper plate **94** and the middle plate **95** is for example, about 100mm. A gap h_2 between the upper plate **94** and the lower plate **96** is for example, about 165mm, and a gap h_3 between the upper plate **94** and the handle **92a** is for example, about 200mm. After the plurality of tubes **100** are set in the holding tool **90**, the holding tool **90** is disposed in the container **72.** Then, elevating and lowering the liquid surface **60a** is repeated a plurality of times, and thus the plurality of glass tubes **100** can be cleaned. The end of cleaning can be determined with the concentration monitoring meter **80.**

In order to prevent impurities (e.g., alkaline components) contained in the ambient air surrounding the cleaning apparatus **70** from entering the container **72,** as shown in FIG. **5,** the container **72** can be of an airtight structure. More specifically, after the holding tool **90** in which glass tubes **100** are set is disposed in the container **72,** an inert gas (e.g., Ar) **84** is filled in the container **72,** and then a lid **78** is attached so that the opening on the top face of the container **72** is sealed. Also in order to prevent the ambient air from entering the container from the discharge pipe **76,** a discharged liquid receptacle **86** is provided in an outlet (the other end) **76b** of the discharge pipe **76** and an inert gas **84** is filled in the discharged liquid receptacle **86.** Alkaline components are contained in the air in some

concentration, and the concentration is larger in seaside areas. Therefore, it is preferable to use the container **72** of an airtight structure to clean the glass tubes **100** in order to obtain the glass tubes **100** whose impurities level is maintained at the level of the original material (quartz glass).

Embodiment 2

In Embodiment **1**, a method for cleaning a glass tube for a discharge using one kind of cleaning liquid (e.g., pure water) has been described, but the present invention can apply to a method for cleaning a glass tube for a discharge lamp to remove a plurality of kinds of impurities with a plurality kinds of cleaning liquid. Hereinafter, a cleaning method of Embodiment **2** will be described with reference to FIG. **6**. The same description as in Embodiment **1** will be omitted or simplified.

FIG. **6** is a flowchart showing each step of the cleaning method of this embodiment. First, a glass tube **100** for a discharge lamp is set in the holding tool **90** shown in FIG. **4** (step S11**0**), and the holding tool **90** in which the glass tube **100** is set is disposed in a container **72** of a first cleaning apparatus **70** (see FIG. **3**). A hydrofluoric acid aqueous solution is supplied as the cleaning liquid **60** to the container **72** of the first cleaning apparatus **70**, and the liquid surface **60a** (liquid surface of hydrofluoric acid aqueous solution) in the container **72** of the first cleaning

After cleaning at step **S150**, in order to protect the glass tube **100** from contamination by impurities contained in the ambient air surrounding the glass tube **100**, argon gas is introduced from one end of the glass tube **100**, and allowed to flow while being in contact with the inner face of the glass tube **100**. Then, argon gas is discharged from the other end of the glass tube **100**. Such flow of argon allows the air in the glass tube **100** to be purged by the argon gas, so that the cleaned state after step **S150** can be maintained.

Furthermore, when the air in the glass tube **100** is purged by argon, even if the glass tube **100** is moved, argon stays in the glass tube **100**, and argon in the glass tube **100** is not replaced by the ambient air for a comparatively long time (e.g., about several ten minutes to several hours). Therefore, the purge of the air in the glass tube **100** by argon is also advantageous in that handling of the glass tube **100** becomes easy. In addition to purging the air in the glass tube **100** by argon, fine powder particles (e.g., quartz beads) can be introduced from one end of the glass tube **100**, and the fine powder particles are brought in contact with the inner face of the glass tube **100**, so that impurities or dust attached on the inner face of glass tube **100** (especially inner face **10a** of the luminous bulb portion **10**) can be removed.

Embodiment 3

The translucent tube for a discharge lamp that has been

cleaned by the cleaning method of the above described methods is used to produce a discharge lamp. Hereinafter, a discharge lamp produced with the translucent tube for a discharge lamp that has been cleaned by the cleaning method of the above described methods will be described with reference to FIGS. **7** to **11**. The same description as in the above embodiments will be omitted or simplified.

FIG. **7** is a flowchart showing a production process of a discharge lamp of this embodiment.

First, a quartz glass tube for a discharge lamp is prepared as a translucent tube for a discharge lamp (step **S100**). The glass tube prepared in this embodiment is the same as that of Embodiment **1** (see FIGS. **1**, **2A** and **2B** or the like). In this embodiment, a glass tube for a discharge lamp is used, but a ceramic tube for a discharge can replace the glass tube for a discharge lamp.

Next, the glass tube is cleaned in the manner as described in the above embodiments (step **S200**). This step provides a glass tube that has been cleaned to the level of the impurities contained in the material (quartz glass) constituting the glass tube.

Then, using the cleaned glass tube, a known lamp production process (step **S300**) is performed, so that a discharge lamp is completed. The lamp production process primarily includes an electrode insertion process (step **S310**) and a sealing portion formation process (step **S320**). These processes will be described briefly with reference to FIGS.

8A and **8C**.

First, as shown in FIG. **8A**, an electrode assembly **50** including a metal foil (Mo foil) **24** and an electrode **12** connected to the metal foil **24** is inserted into the side tube portion **20** of the cleaned glass tube **100** (step **S310**). In this process, the electrode assembly **50** is inserted so that the head of the electrode **12** is positioned inside the luminous bulb portion **10** and the metal foil **24** is positioned inside the side tube portion **20**. A coil is wound around the head of the electrode **12**, and the coil has a function to reduce the temperature at the electrode head during lamp operation. An external lead **26** is connected to the metal foil **24** of the electrode assembly **50** on the side opposite to the side connected to the electrode **12**.

Next, as shown in FIG. **8B**, the pressure in the glass tube **100** is reduced (e.g., less than one atmospheric pressure), and the side tube portion **20** of the glass tube **100** is heated and melted with a burner **54**, so that the side tube portion **20** and the metal foil **24** are attached so that the sealing portion **22** is formed (sealing portion formation process **S320**). Thereafter, a rare gas, halogen and mercury are enclosed in the luminous bulb portion **10**, and then the other side tube portion **20** is subjected to the electrode insertion process **S310** and the sealing portion formation process **S320**, and a pair of sealing portions **22** seals the luminous bulb **10**. Then, as shown in FIG. **8C**, a discharge lamp **1000** can be obtained. In the thus produced discharge

lamp **1000**, the impurities are removed more satisfactorily than an uncleaned glass tube or a glass tube cleaned by the cleaning method shown in FIG. **12**, so that the discharge lamp of this embodiment can exhibit more excellent characteristics (e.g., longer lifetime) than those of conventional lamps

FIG. **9** shows the structure of the discharge lamp **1000** of this embodiment. The discharge lamp shown in FIG. **9** is a mercury lamp (e.g., high pressure mercury or ultra high pressure mercury lamp), and includes a luminous bulb **10** made substantially of quartz glass and a pair of electrodes **12** and **12'** disposed in a space (discharge space) **15** in the luminous bulb **10** and made substantially of tungsten. In the discharge space **15** of the luminous bulb **10**, at least mercury **18**, and a rare gas and halogen are enclosed. The main purposes for this enclosure are as follows. The mercury **18** is enclosed as a luminous material, and the rare gas is enclosed as a gas for smooth start, and halogen is enclosed to activate the halogen cycle.

In this embodiment, the mole number of halogen enclosed in the luminous bulb **10** is larger than the sum of the total mole number of metal elements that have the property of bonding to halogen (except for tungsten and mercury) and are present in the luminous bulb **10**, and the mole number of tungsten that is evaporated from the electrodes **12** and **12'** during lamp operation and is present in the luminous bulb **10**. Typical examples of metal elements having the property of bonding to halogen are alkali metal elements (Na, K, etc.),

when excluding tungsten element and mercury element. The reason that the mole number of halogen is defined as above is described in detail in International Application No PCT/JP00/04561 (International filing date July, 6, 2000, Applicant: Matsushita Electric Industrial Co. Ltd.), which is incorporated herein by reference.

The reason that the mole number of halogen is defined will be described briefly. When the mole number of halogen is defined as above, halogen that can contribute to the halogen cycle can be constantly present in the luminous bulb **10**, so that the activation of the halogen cycle can be ensured. Thus, blackening occurring in the luminous bulb **10** can be prevented. This prevention of blackening prolongs the life of the lamp (e.g., 5000 hours to 10000 hours or more), even if the lamp is used under high output conditions (the bulb wall load of the luminous bulb is for example, $80W/cm^2$ or more) that may end the lamp life early in the prior art. The following is a possible reason why the mole number of halogen was not defined in the prior art. The mechanism of blackening was not examined based on the phenomenon of actual lamp operations under high output conditions. In addition, as described above, it was conventionally believed that alkaline components were hardly attached on the glass tube **100** for a discharge lamp that was handled with care so as not to attach impurities.

In the discharge lamp of this embodiment, impurities present in the inner face of the luminous bulb are removed

satisfactorily by the cleaning method of the above embodiments. Therefore, with the amount level of enclosed halogen that does not interfere with lamp operation, it can be easily realized that the mole number of halogen is larger than the sum of the total mole number of the above-described metal elements and the mole number of evaporated tungsten. On the other hand, in the case of a discharge lamp produced with a uncleaned glass tube or a glass tube that has been cleaned by the cleaning method shown in FIG. **12**, there are a large amount of impurities that have not been removed in the luminous bulb **10**, so that it is virtually difficult that the amount level of enclosed halogen that does not interfere with lamp operation satisfies the halogen mole number condition defined as above, which was experimentally confirmed by the inventors of the present invention.

In view of the case where one metal atom can be bonded to a plurality of halogens, a preferable mole number of halogen to be enclosed is as follows. When each kind of metal elements (except for tungsten element and mercury element) having the property of bonding to halogen is **Mi**, the mole number of halogen of a metal element **Mi** is **mi**, and the stoichiometric coefficient of the metal element **Mi** is **ni**, it is preferable that the mole number of halogen is larger than the sum of the total number ($\sum(mi \times ni)$) obtained by adding the numbers obtained by multiplying the mole number **mi** of the metal element **Mi** by the stoichiometric coefficient **ni** with respect to each kind of the metal elements **Mi**, and the mole

molybdenum is electrically connected to one end of the metal foil **24.** The rated power is 150W (corresponding to a bulb wall load of about 85W/cm^2).

The discharge lamp **1000** of Embodiment **3** can be formed into a lamp **1200** provided with a reflecting mirror in combination with a reflecting mirror **180**, as shown in FIG. **10.** If the lamp **1200** provided with a reflecting mirror is combined with a housing (not shown) for supporting the lamp, a lamp unit can be formed. FIG. **10** schematically shows a cross-section of the lamp **1200** provided with a reflecting mirror.

The lamp **1200** provided with a reflecting mirror includes the discharge lamp **1000** including a substantially spherical luminous portion **10** and a pair of sealing portions **22**, and a reflecting mirror **180** for reflecting light emitted from the discharge lamp **1000.**

The reflecting mirror **180** is designed to reflect the radiated light from the discharge lamp **1000** so that the light becomes, for example, a parallel luminous flux, a condensed luminous flux converged on a predetermined small area, or a divergent luminous flux equal to that emitted from a predetermined small area. As the reflecting mirror **180**, a parabolic reflector or an ellipsoidal mirror can be used, for example. In the example shown in FIG. **10**, a lamp base **55** is attached to one of the sealing portion **22'** of the discharge lamp **1000**, and an external lead **26** extending from the sealing portion **22** and the lamp base **55** are electrically connected.

The sealing portion **22** attached with the lamp base **55** is adhered to the reflecting mirror **180**, for example, with an inorganic adhesive (e.g., cement) so that they are integrated. A lead wire **185** is electrically connected to the external lead **26** of the sealing portion **22** positioned on the front opening side of the reflecting mirror **180**. The lead wire **185** extends from the external lead **26** to the outside of the reflecting mirror **180** through an opening **182** for a lead wire of the reflecting mirror **180**. For example, a front glass can be attached to the front opening of the reflecting mirror **180**.

Such a lamp unit can be attached to an image projection apparatus such as a projector employing liquid crystal or DMD, and is used as the light source for the image projection apparatus. The discharge lamp and the lamp unit of the above embodiments can be used, not only as the light source for image projection apparatuses, but also as a light source for general illumination or ultraviolet steppers, or a light source for an athletic meeting stadium, a light source for headlights of automobiles or the like.

In Embodiment **3**, the lamp enclosing mercury in an amount of 150mg/cc has been described as an example. However, the amount is not limited thereto, and can be larger or smaller. In other words, in Embodiment **3**, the case where the mercury vapor pressure is about 20MPa (the case of so-called ultra high pressure mercury lamp) has been described. However, the present invention can apply to a high pressure mercury lamp in which a mercury vapor pressure is about 1MPa.

Furthermore, the gap (arc length) between the pair of electrodes **12** can be short, or can be longer than that. The high pressure discharge lamps of Embodiment **3** can be used by either lighting method, alternating current lighting or direct current lighting.

Furthermore, instead of mercury or with mercury, a metal halide can be enclosed. More specifically, in Embodiment **3**, a mercury lamp employing mercury as a luminous material has been described as an example of a high pressure discharge lamp. However, the present invention can apply to a high pressure discharge lamp such as a metal halide lamp in which a metal halide is enclosed. However, in the configuration of the discharge lamp of Embodiment **3**, it is preferable that the amount of enclosed mercury is about 200mg/cc or less. This is preferable because with an amount of enclosed mercury of more than that, the pressure in the luminous bulb **10** is too high during operation, so that airtightness cannot be maintained in a portion of the molybdenum foil **24** of the sealing portion **22** and it is highly possible that the lamp is damaged. If it is ensured that the airtightness can be maintained, the amount of enclosed mercury can be larger than 200mg/cc. When the amount of enclosed mercury exceeds 200mg/cc, the thermal conductivity of the gas in the luminous bulb **10** becomes high. Therefore, the heat of discharge plasma easily propagates to the electrodes **12** or the luminous bulb **10** (quartz glass), which further raises the temperature, so that impurities more

significantly leak from the glass or the electrodes. Therefore, in the case where mercury is enclosed in an amount of more than 200mg/cc, the advantage of the lamp **1000** of Embodiment **3** produced with a glass tube made of a material having a high purity that has been cleaned satisfactorily is highly distinguished.

Furthermore, in Embodiment **3**, the case where the bulb wall load is about $80W/cm^2$ has been described as an example, but the bulb wall load is not limited thereto. The bulb wall load can be smaller or larger than that. In the case of a higher load, a lamp is operated in a high temperature, and therefore impurities significantly leak from the glass or electrodes. Therefore, the advantage of the lamp **1000** of Embodiment **3** produced with a glass tube made of a material having a high purity is highly distinguished. However, in the configuration of the discharge lamp of Embodiment **3**, it is preferable that the bulb wall load is about $100W/cm^2$ or less. This is preferable because with a load of more than that, the temperature of the luminous bulb **10** is too high, so that deformation or deterioration due to heat may occur. In this case, if these problems can be avoided by adding another means for cooling the luminous bulb **10**, the bulb wall load can be larger than $100W/cm^2$.

Furthermore, in Embodiment **3**, the case where the rated power is 150W has been described as an example, but the rated power is not limited thereto, and can be more than 150W or less than 150W. However, the configuration of the discharge

lamp of Embodiment **3** is particularly suitable for a lamp having a comparatively large power of 50W or more. Since a lamp having a large power is operated in a higher temperature, impurities significantly leak from the glass or the electrodes. Therefore, the advantage of the lamp **1000** of Embodiment **3** made of a material having a high purity is highly distinguished. As the discharge lamp of Embodiment **3**, a lamp enclosing bromine (Br) as halogen has been described as an example, but halogen can be replaced by chlorine (Cl) or iodine (I).

The invention may be embodied in other forms without departing from the spirit or essential characteristics thereof. The embodiments disclosed in this application are to be considered in all respects as illustrative and not limiting. The scope of the invention is indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.